Photoluminescence of Mg-diffused GaN epilayer

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Research on gallium nitride (GaN)-based materials and the related semiconductor optoelectronic devices have attracted much attention because of their wide applications. The current development issue of GaN-based devices has been the p-type GaN formation. Both in-situ Mg doped [1] and post-growth Mg diffused [2] p-type GaN were demostrated. In this paper, we studied the optical properties of p-type GaN that was formed by Mg diffusion into MOVPE grown undoped n-type GaN using Mg_3N_2 as the Mg source. The MOVPE grown GaN on sapphire with about 2 μm thick undoped layer with an n-type carrier concentration ~$5*10^{16}$ cm^{-3} was sealed with Mg_3N_2 powder in a vacuum quartz ampoule. Then the ampoule with the GaN sample was put in a 950°C furnace for diffusion process. The Mg diffusion profile measured by SIMS showed that the carrier concentrations over entire 2 μm GaN layer were at the range of 10^{18}~10^{20} cm^{-3}.

The GaN samples (S0, S1, S2, S3, and S4) were characterized by temperature-dependent photoluminescence (PL) experiment. Fig. 1 shows 5 energy features (E1 to E5) on the PL spectrum for undoped GaN sample (S0) at low temperature (50K) has been observed clearly. The PL spectrum was fitted by Gaussian function and the energy values are listed in Table 1. Four features (E1, E3, E4 and E5) are identified as D^0X, donor to acceptor pair (DAP), DAP-1LO (longitudinal phonon), and DAP-2LO optical transitions [3]. However, the origin of the E2 optical transition is unclear. The energy feature E2 may be due to the band tail edge or bandgap transition of partial cubic phase GaN [4]. The PL spectra for all samples at low temperature (50K) are shown in Fig. 2 and the peak height of D^0X transition are normalized for viewing the Mg-diffused effect. The DAP intensity increases as diffusion time increases.

Two upper transition energy of temperature-dependent PL spectrum above temperature 150K were compared with theoretical calculation using a Varshni's equation and published data [5] and the results are also shown in Fig. 3. The trend of the temperature dependence of the E1 and E2 both are similar to band to band transition. Therefore, the interpretation of the D^0X and E1 is reasonable. The results show that the longer diffusing time at constant temperature (950°C) improves the optical properties of GaN epilayer and the Mg activation. In summary, the PL spectroscopy has characterized Mg-diffused GaN epilayer. The measured energy features of the optical transition have been identified and the extra peak below the D^0X transition is observed clearly.

References

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Table 1 Summary results of the transition energies of all the samples at 50K.

Sample	E5(eV)	E4(eV)	E3(eV)	E2(eV)	E1(eV)
S0	3.095	3.185	3.274	3.412	3.478
S1	3.069	3.191	3.277	3.412	3.474
S2	3.124	3.200	3.282	3.400	3.474
S3	3.106	3.196	3.279	3.400	3.469
S4	3.108	3.188	3.270		3.469
ID	DAP-2LO	DAP-1LO	DAP	BTE(?)	D^0X ,FX A

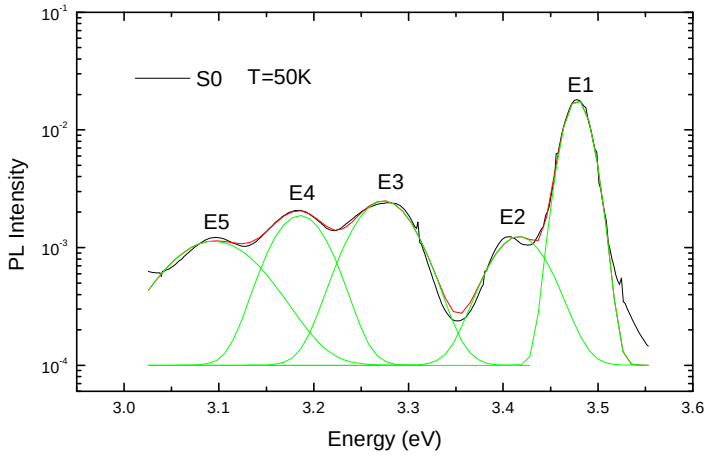

Fig. 1 The PL spectrum of sample S0 at low temperature. The solid line is fitted by Gaussain function.

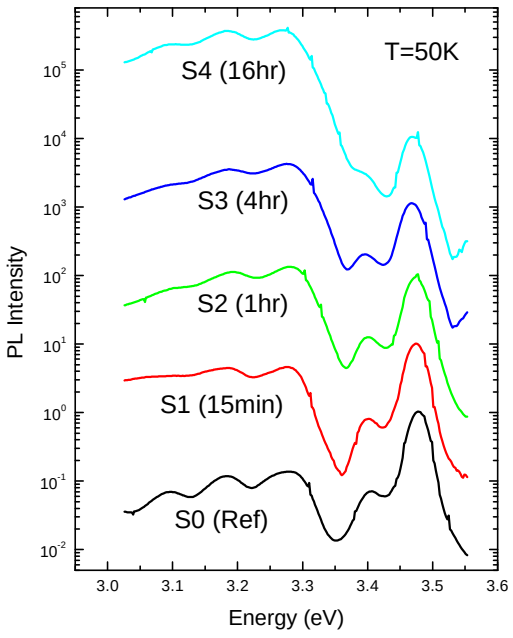

Fig. 2 PL spectra for varied diffusion time (shown in parentheses) at low temperature. Each spectrum is offset-shift by one-decade order for viewing.

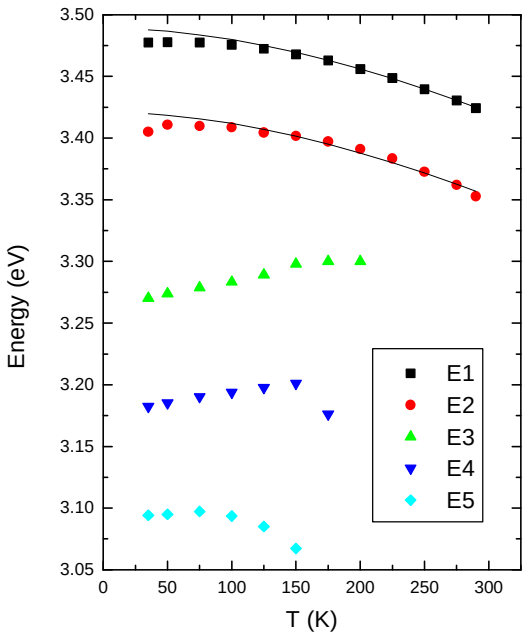

Fig. 3 The temperature dependence of transition energies for sample S0. The solid curve is calculated by Varshni's eq. using published data[5].